

Chapter 7

Hydrologic Engineering Requirements for Flood Damage Reduction Measures

7-1. Overview

This chapter provides an overview of the hydrologic engineering analyses necessary for the major structural and nonstructural measures of flood damage reduction studies. The types of analyses and hydrologic methods described in the previous chapters are used to show the analysis requirements for different types of measures.

7-2. Without-Project Conditions

a. Flood damage analysis. Corps of Engineers flood damage reduction analyses for different projects, both structural and nonstructural, are similar in method. The first step is the analysis of the discharge or stage versus frequency of flooding relationships at key points in the stream system for the existing or base project conditions. This step is repeated for at least one time in the future, assuming future land use conditions will result in changing discharge/stage versus frequency relationships. The development of existing and future, without-project hydrologic and hydraulic relationships is critical to establish the magnitude of the flood problem so that flood damage analyses may be performed. The flood damage analysis provides insight as to the location and the amount of existing and future expected damage, and therefore the amount of project costs that one could spend to mitigate the flood damage.

b. Hydrologic engineering studies. Hydrologic engineering studies normally require considerable time establishing the existing and future without-project relationships by performing rainfall-runoff, frequency, river hydraulics and reservoir operation studies. Specific methods used during the analysis of each flood damage reduction measure are based on the amount of data available, the complexity of the study area, and the needs of the Interdisciplinary Planning Team (IPT).

7-3. Screening of Alternatives

a. Structural measures. Following development of without-project conditions, analysis of different structural and nonstructural flood damage reduction measures is performed. Not all measures presented in this chapter would likely be evaluated in a specific study. Rather, the IPT, including representatives of various Corps disciplines

and the local cost-share partner, would identify one or more likely feasible measures and plans to evaluate for the study area. Reservoirs are practical because they reduce flooding at downstream locations; however, they are often the most costly alternative and the most difficult to economically justify. If flood damage reduction is for a single site along a stream, a local protection project (channel modification, levee, or diversion) would be examined. These projects are normally less costly than a reservoir and provide site-specific protection to a single area. However, local protection projects can have adverse effects on flooding elsewhere.

b. Nonstructural measures. Nonstructural measures are required to be analyzed as a means of reducing flood damage (Section 73 of Public Law 93-251). Nonstructural alternatives may be examined with structural solutions, or by themselves. These solutions are typically the least expensive, but often provide the least flood damage reduction to the area. If the existing/future without-project damages are small, nonstructural solutions may be the only ones feasible.

7-4. Reservoirs

The intent of flood control reservoirs is to store and gradually release upstream flood runoff after downstream flooding is over. Reservoirs are practical flood damage reduction solutions because they reduce flooding throughout the downstream river system, although the effects of the reservoir decrease as the distance from the reservoir increases. A flood control reservoir is analyzed to accomplish flood damage reduction and to ensure safety of the structure in extreme floods.

a. Flood control.

(1) Flood control analysis determines the storage volume in the reservoir that should be reserved to control flooding. The hydrologic modeling effort requires varying magnitudes of floods to be routed through the reservoir and to downstream damage centers. The analysis yields with- and without- reservoir discharge-frequency relationships. Figure 7-1 illustrates this analysis.

(2) Historic data for the routings are preferred and are usually available for sites in larger rural areas. Urban reservoirs usually have little or no data and synthetic rainfall-runoff modeling is normally employed. Discharge is converted to stage at downstream locations to determine project damage. The difference between with- and without-project damage is the flood inundation reduction benefits attributed to the project.

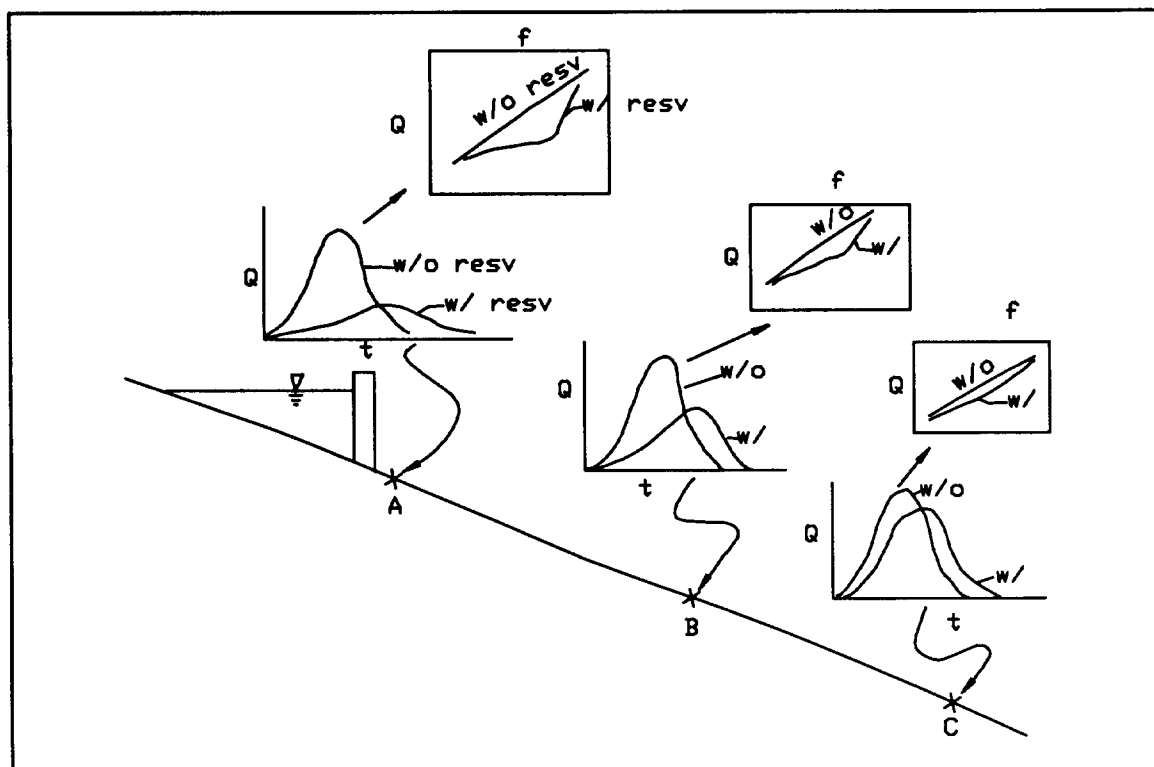


Figure 7-1. Effects of a reservoir

b. Safety. A safety analysis specifically determines the height of dam and size of spillway necessary to ensure that essentially no risk of dam overtopping exists. For high hazard dams, where overtopping would cause a downstream catastrophe, a very high safety design standard - typically the Probable Maximum Flood should be selected.

7-5. Local Protection Projects

Channels, levees, and diversions are considered local protection projects. Protection of a specific damage center is accomplished with each, although channelization, levee systems, and major diversions have been constructed to protect a series of damage centers. Each project reduces the severity and frequency of flooding to the protected area. They may, in unusual circumstances, also increase flooding immediately adjacent to the protection area.

a. Channels.

(1) New channels or modifications to existing channels attempt to decrease flood stage by increasing channel efficiency. The effect of a channel project is illustrated in Figure 7-2.

(2) Channelization is a typical measure for urban flooding situations. An improved channel can provide a smoother flow path (less boundary friction), increase the cross-sectional area of the channel, improve the efficiency of the channel, or combinations of these changes. If an extensive reach of channelization is to be constructed, the effects of these changes will be to increase the severity of downstream flooding by accelerating the flood hydrograph through the reach, causing higher peak discharges downstream. The hydrologic analysis must address this problem, as well as the beneficial effects of channelization. River hydraulics dominate channelization studies, with storage routing becoming more important in determining adverse effects as the channel reach becomes longer.

b. Levees and floodwalls.

(1) Levees and floodwalls prevent floodwaters from entering the protected area until the design event is exceeded and the levee or floodwall is overtopped. Figure 7-3 illustrates the usual effect of a levee or floodwall for the area protected and for unprotected areas upstream.

(2) River hydraulics is the major analysis component for evaluating levee grade and alignment, as well as

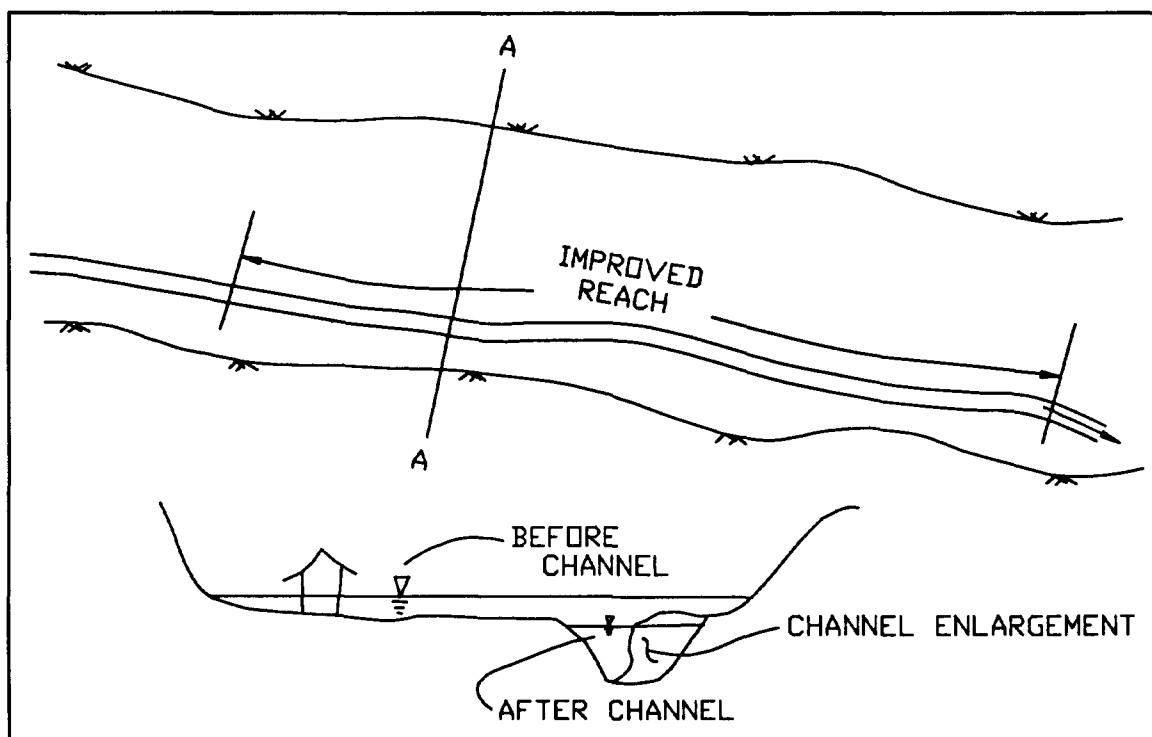


Figure 7-2. Effects of a channel

certain adverse effects. Upward shifts in river stage for the same discharge may occur when the levee or flood-wall confines the flood to areas outside the protected area. This effect may extend upstream from the levee unit, inducing additional flooding to unprotected areas.

(3) An extensive levee project or a system of levee projects can remove significant floodplain storage. This lost storage can result in increases in peak discharge downstream of the levee(s). Hydraulic routing is required to satisfactorily evaluate storage effects on flood magnitude.

(4) Levees have the potential in unusual circumstances for inducing flooding, both upstream and downstream of the protected area. Thus, the hydrologic design should minimize these adverse effects as much as practical.

(5) Levees and floodwalls greatly reduce the direct threat of flooding by the main river or lake. However, the nature of this solution may introduce a secondary flood problem, which is the remaining or residual interior area flooding. This flooding results from interior ponding by rainfall on the leveed interior, blockage of existing flow paths, and seepage water through the levee during

high interior stages. During lengthy high exterior stages, interior flooding caused by interior ponded water could negate much of the damage prevented by the levee or floodwall. Therefore, an interior flood control analysis is an integral part of any levee or floodwall project. Rain-fall-runoff analysis and storage operations are the dominate features of interior flood control analyses. These analyses are complex because they must address the joint probability of high river stages and of significant interior runoff. Period-of-record analysis is preferred, but gaged data are seldom available for an accurate application. Hypothetical events are often used. Interior flood control studies are among the most difficult hydrologic engineering analysis. EM 1110-2-1413 provides additional information on these complex studies.

c. *Diversions.* These components remove water from the main channel upstream of the area to be protected, and usually reintroduce the diverted water downstream of the area. Figure 7-4 illustrates the impact of a diversion. River hydraulics is the dominate means of analysis. The potential exists for adverse effects on flood heights downstream of the diversion reentrance. This problem would be analyzed through storage operations.

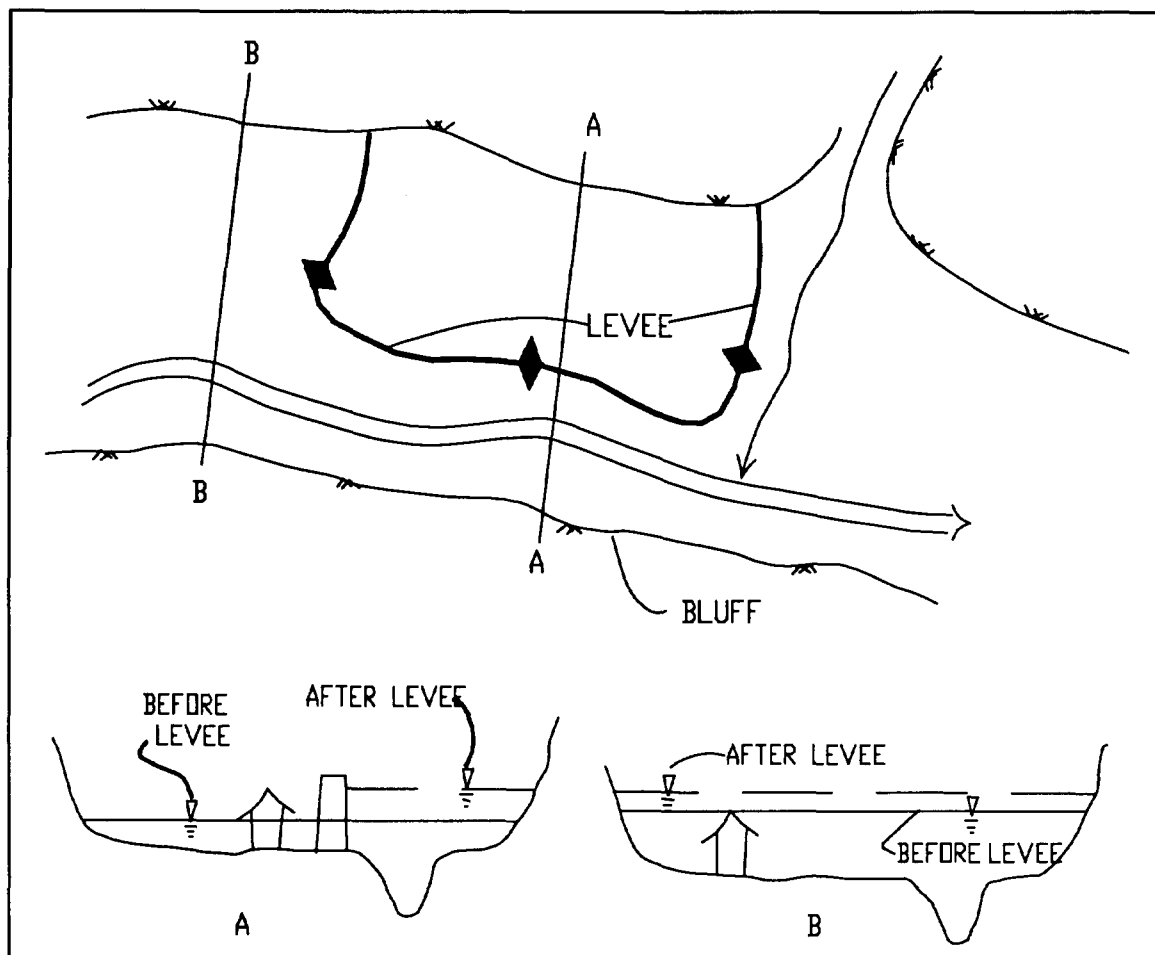


Figure 7-3. Effects of a levee/floodwall

7-6. Nonstructural Measures

Structural solutions modify the watershed's hydrology/hydraulics to reduce flood damage to the protected area(s). Nonstructural measures operate in a reverse fashion, by reducing the damage potential in the flood-prone area without changing the hydrology and hydraulics of the watershed. Rainfall-runoff, frequency, river hydraulics, and storage operations may be utilized in development of existing hydrologic/hydraulic conditions. Nonstructural measures include: floodplain management and flood insurance, floodproofing, relocations, and flood warning-preparedness planning. A reference (Hydrology Subcommittee 1985) further describes nonstructural analyses.

a. Floodproofing. This alternative minimizes damage by raising the elevation where floodwaters first enter a structure. Usual means of floodproofing are the installation of waterproof shields to doorways and basement

windows. Two feet is the practical maximum depth for floodproofing before the pressure of water on exterior walls could result in structural failure. Floodproofing applications are most suitable when first-floor flooding is more frequent than a 5-percent chance event, and the difference between frequent and infrequent flood elevations is 1 to 2 feet.

b. Relocation. This alternative refers to permanently moving flood-damageable items to a higher elevation (second floor, etc.) or moving the entire structure to higher ground. Moving the structure is most feasible when flooding of the first floor is more frequent than a 5-percent chance (20-year) event and the structure has sufficient value for relocation to be economically justified.

c. Flood warning-preparedness planning. This alternative refers to a formal system and plan for ascertaining that a flood threat is imminent and ensuring that

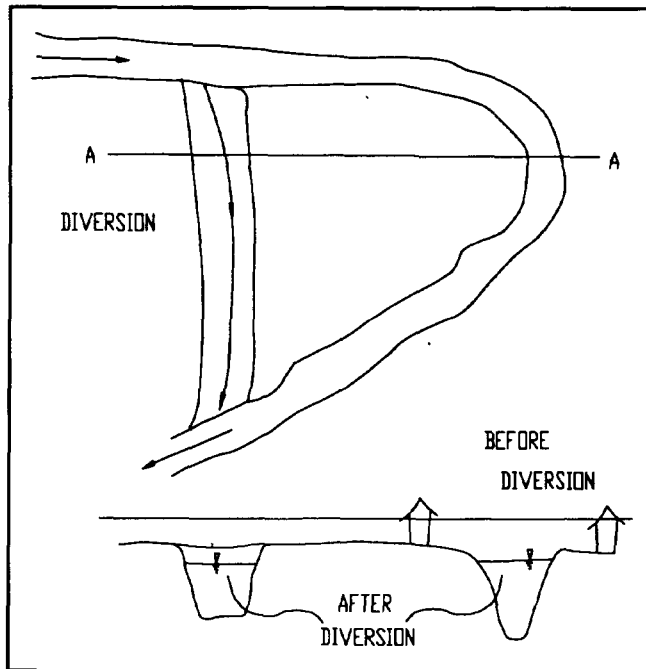


Figure 7-4. Effects of a diversion

appropriate actions are taken to minimize the threat to human life and decrease flood damage. The system usually includes rainfall and river gages upstream of the damageable area, a communication network to get the measured information to the appropriate personnel, a forecast model or other indicator to estimate flood severity and a detailed response plan to address all necessary actions. In addition to the need to identify flood

stages at key locations for different flood events, adequate warning time is needed to take the appropriate actions. The measured information and the forecasting model must be accurate to minimize the threat of false alarms and resulting loss of confidence in the system. The complexity of the system must be commensurate with the ability of the sponsor to operate and maintain the system.

7-7. Floodplain Management Studies (FPMS)

These studies include floodplain management reports, flood hazard reports, and flood insurance studies. The FPMS program is intended to provide flood information for wise land use planning by local communities. Knowledge concerning future flood levels is instrumental in preventing development of flood-prone land. The hydrology and hydraulics performed for flood insurance studies also provide the technical basis for the purchase of flood insurance by individuals already occupying the floodplain. Flood insurance studies also require additional river hydraulics studies to establish a floodway, normally for the 1-percent chance event. The floodway specifies the portion of the floodplain that can be encroached without adversely affecting upstream flood heights more than a specified amount, normally 1 foot.

7-8. Hydrologic Analysis Requirements Summary

The type of technical studies required to analyze specific flood damage reduction measures are shown in Table 7-1. The information presented in Table 7-1 should be considered typical and may vary depending on specific study conditions and requirements.

Table 7-1
Hydrologic Analysis Needs for Flood Damage Reduction Measures¹

Measure	Rain-Runoff(1)			Frequency			River Hydraulics		Storage Operations		
	A(2)	B	C	D	E	F	G	H	I	J	K
Reservoirs											
Flood Control	Y(3)	Y	Y	Y	Y	X	Y	Y	Y	Y	X
Safety	X	Y	X	N	N	N	Y	N	Y	Y	N
Channels											
Levees	Y	Y	Y	X	Y	N	Y	X	X	X	N
Interior Flood Control	X	Y	Y	N	Y	N	X	N	Y	Y	X
Diversions	Y	Y	Y	X	Y	N	Y	X	X	X	N
Floodplain Management	X	Y	N	X	Y	N	Y	N	X	N	N
Nonstructural	X	Y	N	X	Y	N	Y	N	X	N	N

(1) Dominate analysis types but not necessarily done for every case. For instance, historic frequency analysis would be done for interior flood control studies if the data were available.

(2) (A) Reconstitute historic floods, (B) develop hypothetical floods, (C) analyze the changed discharge/stage-frequency, (D) develop historic data, (E) develop from hypothetical events, (F) volume-duration studies, (G) elevation (stage) conversion from discharge, (H) sediment transport/deposition analyses, (I) routing operations, (J) facility sizing by routing, (K) sequential (period of record) routing.

(3) Y Usually done (major part of study), X Done less often (not a major part of study), N not usually done.

¹ In general, not a detailed specification.